BIG CREEK HYDROELECTRIC SYSTEM, POWERHOUSE 8 HAER CA-167-G
(Big Creek No. 8) *HAER CA-167-G*
Confluence of Big Creek and San Joaquin River, about 4.8 miles west of Big Creek
Big Creek vicinity
Fresno County
California

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

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BIG CREEK HYDROELECTRIC SYSTEM, POWERHOUSE 8
(Big Creek No. 8)

HAER No. CA-167-G

LOCATION: Confluence of Big Creek and San Joaquin River, about 4.8 miles west of Big Creek
Big Creek vicinity, Fresno County, California

STRUCTURAL TYPE: Reinforced concrete and steel power generation building

DATE OF CONSTRUCTION: 1921

DESIGNER: Southern California Edison Construction Department

BUILDER: Southern California Edison Construction Department

PRESENT OWNER: Southern California Edison, Northern Hydro Division

PRESENT USE: Hydroelectric generation facility

SIGNIFICANCE: Constructed in 1921, Big Creek Powerhouse 8 was part of the great expansion of the Big Creek system by Southern California Edison between 1920 and 1929. Planned and constructed quickly to help ease a power crisis in Southern California Edison's Los Angeles-area service territory, Big Creek 8 marked a number of firsts. It was among the first plants to use the improved Francis-type vertical turbine, which allowed high efficiencies at relatively low heads. It set records for the speed of its construction, just 100 days from groundbreaking to operation. Powerhouse 8 was the first plant in the world designed for transmission at 220kV, and in 1923 was the first in the world to transmit commercial power at that voltage. It also reflects the architectural trend toward separating generation and transmission equipment at power plants: these functions are segregated in separate buildings.

The Big Creek system was the premiere Western example of the transition from the construction of isolated power plants serving local markets to the construction of large integrated systems connected to distant energy markets via high-voltage transmission. The system is also significant in the history of the Los Angeles region. Conceived as a means of powering both residential development and electric railways, power from Southern

California Edison's Big Creek plants was instrumental in the rise of suburban development in the region.

The system is closely associated with railroad, energy, and development magnate Henry Huntington; with Edison executives and power pioneers A.C. Balch, William Kerckhoff, and George C. Ward; visionary California hydroelectric engineer John Eastwood; and longtime Big Creek manager David Redinger.

HISTORIAN: Daniel Shoup, PhD
Archaeological/Historical Consultants, Oakland, California

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This report is presented as one of a series of HAER reports on the early Big Creek powerhouses, including Powerhouses 1, 2/2A, 3, and 8, and Operator's Cottage 115. These studies focus on the period from 1912, when construction began, to 1929, the end of the "great expansion" of the Big Creek system. Previous research has identified 1912-1929 as the period of significance for the system as a whole.

This study focuses on the history of the powerhouse structure itself. Other features of the Big Creek system, such as dams, tunnels, penstocks, residences, forebays, outdoor substations, and power lines are not treated in detail. Similarly, the social history of Big Creek town and other communities in the vicinity are touched on only briefly in this text.

Many publications and technical reports offer more detail on the Big Creek system. Former Big Creek superintendent David Redinger's *The Story of Big Creek* remains a key reference work.[1] Other important works include historic studies and significance evaluations of the system and the town, one of which is appended as Field Notes to CA-167-E.[2] Previous HAER reports on parts of the Big Creek system were also prepared by Thomas T. Taylor of Southern California Edison.

HAER reports for the Big Creek System prepared to date include:

- Operator Cottage, Big Creek # 8 (HAER CA-167-A)
- Big Creek #3 penstock standpipes (HAER CA-167-B)
- Operator Cottage 105, Big Creek Town (HAER CA-167-C)
- Operator House Garage, Big Creek Town (HAER CA-167-D)
- Big Creek Powerhouse 1 (HAER CA-167-E)
- Big Creek Powerhouse 2/2A (HAER CA-167-F)
- Big Creek Powerhouse 8 (HAER CA-167-G)
- Big Creek Powerhouse 3 (HAER CA-167-H)
- Operator Cottage 115, Big Creek Town (HAER CA-167-I)

See the bibliography for this report and the other reports in the series for more complete references. Copies of historic photographs have been included in the field records accompanying this documentation.

[1] David H. Redinger, *The Story of Big Creek* (Los Angeles: Angelus Press, 1949).
[2] Laurence H. Shoup, *"The Hardest Working Water in the World": A History of and Significance Evaluation of the Big Creek Hydroelectric System*, report prepared for Southern California Edison Company, Rosemead, CA, 1987; Laurence H. Shoup, *Life at Big Creek Town 1929-1947: Historic Context Statement and National Register of Historic Places Significance Evaluation*, Southern California Edison Company, Rosemead, CA, 1997.

STYLE AND CONSTRUCTION

Setting and style

Big Creek Powerhouse 8 is located on Big Creek, at its confluence with the San Joaquin River in Fresno County, California. The surrounding landscape of sheer cliffs and undeveloped hills is covered in oak and pine. Constructed in 1921, the powerhouse is located on the south bank of Big Creek and consists of two engaged concrete and steel structures (Views CA-167-G-1 through CA-167-G-3). The lower, streamside structure contains the generating equipment. The upper structure, which is cut into the slope of the hillside, contains the transmission substation. The operating area of Powerhouse 8 is depicted in View CA-167-G-44.

Like Powerhouses 1 and 2 (1913), Powerhouse 8 is a reinforced concrete and steel industrial modern structure with neoclassical façade detail. The generator room rises from Big Creek on a massive foundation of reinforced concrete resting in the stream and runs east-west along its long axis.

On the east and west elevations of the generator room, four pilasters frame three recessed areas, each with two window openings. On the east elevation, the lower left opening is a rolling steel door (see Views CA-167-G-45 through CA-167-G-47). The east or upstream end of the building was originally fitted with a temporary wall that was extended to its current, permanent dimensions in 1928.

The river or north façade of the generating room has five pilasters and an area of blank wall on either end. Recessed between pilasters are four recessed window openings running almost the whole height of the structure. Each large window sits atop a projecting sill. At the west and east ends of the north façade is an area of blank wall with three smaller window openings flush with the wall and set in a vertical line (Views CA-167-G-8, CA-167-G-9, CA-167-G-45, CA-167-G-47). The south façade of the generator room engages the transmission structure.

A projecting stringcourse runs above the pilasters on all sides of the generating structure. On the east and west facades, a gabled roof with massive cornice forms an undecorated pediment. On the north façade, a light steel truss footbridge crosses the forebay to enter the generating room near the lower right corner of the building and in line with the right hand row of window bays (Views CA-167-G-4 through CA-167-G-6).

Like those at Powerhouses 1 and 2, the generator room of Big Creek 8 was designed for later expansion, which occurred in 1928. Initially, the building was only constructed as far south as the fourth central pilaster, with a temporary end of plaster on metal lath. Between 1921 and 1929, then, the east façade of the building presented an asymmetrical appearance (Views CA-167-G-44). The transmission structure engages the southern side of the generating structure and runs east-west on its long axis. Three stories high, it rises above the generating structure. The transmission structure is flat-roofed, with a massive projecting cornice and stringcourse framing an undecorated frieze.

The north façade engages the generating structure, and continues upward with five pilasters and four recessed window bays corresponding to those below. The south façade meets the hillside on its first floor with the exception of the lower left portion, which is occupied by a roller steel door. The upper two floors have pilasters with recessed panels corresponding to those on the other side. However only three small window openings are present on the second floor, and none on the third floor (Views CA-167-G-9, CA-167-G- 46).

On the east elevation six pilasters corresponding to the structural columns form five recessed bays, each with two windows set on projecting sills. The two right-hand (northern) bays have windows of greater height, while those on the left (southern) side are considerably shorter. A ladder and catwalk at the central bay allows exterior access to the upper part of the structure (CA-167-G-46).

The west elevation is similarly organized. However, the right-hand (southern) portion of the third floor is unwalled and the switching equipment inside is open to the air. On the north façade, the western portions of both the second and third floors are open, revealing transmission equipment. At the second floor, an exterior catwalk exits the generator room and stretches along part of the transmission building façade to an access door. As a result of these modifications, the windows on the west elevation appear irregularly spaced (CA-167-G-45).

Powerhouse 8 features large window panels composed of a grid of lights set in metal stiles and rails. Both fixed and pivoting sash are used in the windows, with a small number of louvre windows used in the battery room. Pivoting sash is opened by sash operators on the generator floor and on the floors of the transmission structure. For details of the concrete jambs and sills, see View CA-167-G-57.

The architecture of Powerhouse 8 reflects contemporary architectural trends. American industrial architecture of the early 20th century favored the derivation of architectural form from the frame of the structure, leading to a 'façade grid' determined by the alternation of vertical structural supports and horizontal floors. In elaborating façade details, however, architects often decorated this basic grid with elements derived from formalist styles such as gothic revival or neoclassicism.[3] Powerhouse 8 uses neoclassical architectural gestures, including pilasters, gables, and stringcourses, but does so sparingly. Instead, functionalism dominates the viewer's impression of the structure.

Powerhouse 8, with its two distinct structures and open-air switching porches, reflects the increasing trend in power plant architecture toward segregating the generation and transmission functions and establishing open-air switchyards. Big Creek Powerhouse 3, built in 1923, shows the full development of this trend with its fully outdoor switch yard. Although Powerhouse 8 is a well-preserved example of important trends in American industrial and public utility architecture, it cannot be said to be a uniquely significant, or especially aesthetically successful, example of its architectural style or building type. Rather, the significance of Powerhouse 8 lies in its excellent state of preservation and in its role as part of a pioneering large integrated system

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[3] Betsy Hunter Bradley, *The Works: The Industrial Architecture of the United States* (New York: Oxford University Press, 1999), 231.

of electrical generating plants. As Duncan Hay notes of contemporary hydroelectric systems more generally,

> individual structures and pieces of hardware were seldom significant in and of themselves. Their importance lay in their role within complete power-plants and, in some cases, within basin-wide or regional developments.[4]

As noted above, the Big Creek system remains one of the most significant generation and transmission systems in California and North America.

Design and Engineering

Powerhouse 8 was designed by the Construction Department of Southern California Edison. The architect and designer of the powerhouse are unknown. O.H. Honnold served as electrical foreman, Walter Nauermeister was the foreman for transmission lines, Bill Whitmire was the construction foreman, and Joe Rogers was electrical superintendent in the construction of the plant.[5] E.R. Davis, manager of construction for Southern California Edison, directed the construction.

I.P. Morris sent an erector to supervise the assembly of the hydraulic equipment.[6] General Electric personnel also supervised the assembly of the generator.[7]

Suppliers and Contractors

Valuation Engineers

A main source of data about Powerhouse 8 is found in the Valuations and Unit Cost Developments prepared by Arthur Kelley in 1928 and 1929. Kelley was a consulting valuation engineer who prepared detailed inventories of the Big Creek plants and their contents between 1922 and 1932. After 1924, Kelley or his representatives were on site during many construction tasks to monitor construction practices and record the volumes and nature of materials used. The resulting documents provide a wealth of information and form a major primary source for this report.[8]

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[4] Duncan Hay, *Hydroelectric Development in the United States, 1880-1940* (Washington, D.C.: Edison Electric Institute, 1991), 28.

[5] "Big Creek No. 8 Hydro-Electric Unit Completed," *Journal of Electricity and Western Industry*, August 11, 1921, 160.

[6] Arthur R. Kelley, *Unit Cost Development and Price Book Accompanying Valuation of Electric Properties, Southern California Edison Big Creek No. 8 Development, December 31, 1928*, Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA, 216.

[7] R.E. Smith, "Big Creek Plant adds 300,000 Hp. to Western Power Supply," *Journal of Electricity and Western Industry*, September 1, 1921, 188.

[8] See Kelley, *Unit Cost Development and Price Book*, as well as *Valuation of Electric Properties, Southern California Edison Big Creek No. 8 Development, December 31, 1928*, Federal Project 67, Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA, and *Valuation and Unit Cost Development of Electric Properties, Southern California Edison Big Creek No. 8 Development, Second Unit, 1929*, Federal Project 67 Appendices, Plant Accounting Department, Southern California Edison Company, Rosemead, CA.

Initial Construction (1921)
Aggregate for concrete was produced from tunnel muck by the Southern California Edison Construction Department rock crusher, located at Camp 32. Structural steel for the plant was purchased from the California Steel Company, Oakland, CA. Roofing was installed by Owen Roofing Company, Los Angeles, CA. The traveling crane in the generating room was purchased from Western Manning, Maxwell and Moore, Inc., San Francisco, CA.[9]

The penstock for Unit 1 was supplied by the Lacy Manufacturing Co. and M.W. Kellogg Co. The turbine and governor were manufactured by the I.P. Morris Division, William Cramp and Sons Ship and Engine Building Company. The house turbine was from Allis- Chalmers.[10] The main generator, house generators, transformers, and switchboard panels were purchased from General Electric, Pittsfield, MA.[11]

Unit 2 (1929)
Structural steel for the extension of the generating building was procured from Llewellyn Iron Works. The new roof area was covered with Johns-Manville R-20 roofing, purchased from and installed by the Valley Lumber Company of Fresno, California. Doors in the plant were Kennerson and Kalamein brands, and the window panels were purchased from Detroit Steel Products Co., Los Angeles. The floor finishes in the plant were placed by Continental Building Specialties Company, while the interior paint was Preservo brand.[12]

The Unit 2 turbine and governor were purchased from the Pelton Water Wheel Company of San Francisco, CA. General Electric supplied the Unit 2 generator, exciter, and subexciters for both units. Generator firedoors for Unit 2 were fabricated by the Fernholtz Machinery Company. Circuit breakers were purchased from Westinghouse.[13]

Construction Narrative
The original Big Creek plans called for Powerhouse 3, further down the San Joaquin River, to utilize a head of slightly over 1400’. However, by 1920 improvements in the efficiency of vertical turbines made it possible to obtain a similar amount of energy from heads as low as 700’. When rapidly rising demand created the possibility of power shortages in Los Angeles, Southern California Edison decided in February 1920 to split the head originally designated for Powerhouse 3 into two plants. Tunnel work proceeded through 1920. The new plant was designated Powerhouse 8 because the numbers up to 7 had already been used in designating potential future powerhouse sites in permitting documents.

Excavation at the site of the new plant, designated Powerhouse 8, began January 8, 1921 and was completed on April 30.[14] The first false work for the foundations was built on May 4, 1921, and

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[9] Kelley, *Unit Cost Development and Price Book*, 50, 53, 58-59, 66.
[10] Kelley, *Valuation*, 102, 116-118.
[11] Kelley, *Unit Cost Development and Price Book*, 124, 128, 297.
[12] Kelley, *Valuation and Unit Cost Development*, 75, 79, 80, 82-83.
[13] Kelley, *Valuation and Unit Cost Development*, 38, 48, 160.
[14] Kelley, *Valuation*, 7.

the first concrete was poured on May 21. Installation of the turbine began on June 21, before the structure was complete.

The speed of construction – which set records – led the construction teams to introduce a number of innovative timesaving techniques. As a 1921 article reported:

> An interesting piece of work was done by the men from the General Electric Company who assembled the generator on the job. It was necessary to ship the big castings in two sections and the engineers were of the opinion that if assembled at the factory in two parts the generator would be noisy in operation. When the materials arrived on the job, the building was not far enough along to receive them. Accordingly, a tower 40 feet high was built up from the bed rock and on this the generator was assembled while the construction crew was bringing the building up to that point. When the generator was complete, the false work was knocked out, several weeks being saved by the operation.[15]

The 150-ton capacity traveling crane was also built at a record speed, requiring only eight days for full installation.[16] The plant was nearly complete by the end of July. The penstock was filled for the first time on the evening of August 1, and the house generator was tested the next day. The turbine and generator were tested at low speed on August 7, until a problem with the generator bearing was detected. The plant began generating and transmitting energy on August 11, 1921, just 100 days after the beginning of construction. This pace set records for the time, and earned Powerhouse 8 the nickname of "The Hundred Day Wonder."[17]

The generation building of the powerhouse was extended approximately 38 feet in 1929 to accommodate the addition of the second generating unit. As a result, the generator building took on a symmetrical appearance (View CA-167-G-45). Along with the extension, a number of minor improvements to the plant were carried out, as the 1929 valuation narrates:

> The improvements within the power house consisted principally of providing an office of wood and glass partitions on the third floor of the generator building at the west end adjacent to the stairway, for use of the Station Chief. It was necessary to break the west wall of the existing building to install a window for this office. A stairway was built from the transformer room to the 11kV oil switch room, reinforced concrete partitions were installed of the 11kV circuit breaker cell work. The roof truss over the hoisting well was reinforced to take care of the 200kV oil switches. Because of the rerouting of the 220kV lines, the existing opening for the get-away for the lower bus was closed and a new opening in the east wall for the new get-away was provided. The grade of the entrance foot-bridge to power house was raised, and the bridge extended to road fronting the dormitory.[18]

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[15] Smith, "Big Creek Plant," 188.
[16] Smith, "Big Creek Plant," 188.
[17] Smith, "Big Creek Plant," 188.
[18] Kelley, *Valuation and Unit Cost Development*, 3.

Plans of the switch house addition (CA-167-G-48), generator level (CA-167-G-60, CA-167-G-58), and turbine level (CA-167-G-59) provide more detail.

HISTORICAL CONTEXT

California and Electrical Development of the West

California holds an important place in the history of hydroelectric power generation. Despite relatively low rainfall, especially in the southern regions, the high heads available in the state's mountainous terrain made waterpower important in California's industrial development. The mining industry pioneered the development of dam, flume, and penstock technologies at an early date, while Lester Pelton's development of the Pelton wheel in the 1880s dramatically increased the efficiency of the waterwheel in high head settings.[19] In California, however, this energy was typically located in remote areas far distant from urban centers, restricting its use to industries located nearby.

The development of Thomas Edison's integrated system of dynamos, lamps, and circuitry after 1880 led to a boom in urban electrification. However, widespread dependence on direct current, which had a high rate of transmission loss, made the usefulness of electricity dependent on proximity to a central station. The introduction of alternating current transmission and voltage transformers by George Westinghouse after 1886, however, opened up the possibility of transmitting electricity over long distances.[20] Much of the world's pioneering work in AC transmission took place in California, with early world records for distance and voltage set by transmission lines in Bodie (Standard Consolidated Mining Company, 1891), San Antonio to Pomona (San Antonio Light and Power, 1892), and Folsom to Sacramento (Horatio Livermore, 1893).[21]

Once the potential for connecting hydraulic and electrical power was demonstrated by Westinghouse's development at Niagara Falls (1895), hydroelectric development began in earnest, and nowhere more intensely than in California. Record-setting developments included the first 33 kilovolt (kV) transmission by Southern California Edison's Santa Ana No. 1 plant (1898); use of a 1,300' head in the Mount Whitney Power Company's plant (1899); and, superlatively, the 140-mile, 60kV Colgate transmission line built by Bay Counties Power Company in 1901.[22] "California," claimed the journal *Electrical West* in 1912, "is the birthplace of real long-distance power transmission on this continent."[23]

Southern California Edison's Big Creek project, begun in 1911, was the apex of early twentieth century hydroelectric development in California and was among the world's largest hydroelectric systems at the time of its construction. The system set successive world records for highest voltage ever used in commercial transmission: 150kV (1913) and 220 kV(1923). Powerhouse 1

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[19] Hay, *Hydroelectric Development*, 6.
[20] Hay, *Hydroelectric Development*, 9.
[21] Hay, *Hydroelectric Development*, 19, 28.
[22] Hay, *Hydroelectric Development*, 30; Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983), 277.
[23] Hughes, *Networks of Power*, 265.

and Powerhouse 2A had among the highest heads used in North America – 2,131' and 2,418' respectively. In 1929, at the end of the great expansion of the Big Creek system, the five Big Creek powerhouses (1, 2, 2A, 3, and 8) each held a place among the top ten California hydroelectric plants for kilowatts and horsepower generated.[24]

Origins of the Big Creek System

The Big Creek system was the brainchild of visionary engineer John Eastwood (1857-1924), who first identified the Big Creek and San Joaquin River systems as an ideal location for a series of storage reservoirs and power plants. Eastwood was born in Minnesota and came to California in 1878 to work on the Pacific extension of the Minneapolis and St. Louis railroad. After establishing a private engineering firm in Fresno in 1883, Eastwood turned his attention to the Sierras. In 1893 he first visited the present location of Big Creek town, and saw its potential as the anchor point of a huge hydroelectric generating system. However, demand, distribution, and transmission networks for such quantities of power did not yet exist in California.[25]

By 1895, Eastwood had shown that high-head hydroelectric plants were feasible in the area by developing a plant further down the San Joaquin River for the San Joaquin Electrical Company (today the site of Pacific Gas & Electric Company's Wishon powerhouse). The San Joaquin Electrical Company soon went bankrupt, however, and in 1900 Eastwood turned in earnest to planning and surveying the Big Creek system, securing water rights and identifying locations for tunnels, dams, and power plants.[26] These plans, however, only came to fruition when Eastwood's engineering vision was combined with Southern California capital, in the person of Henry Huntington.

Huntington was born in 1850 in Oneonta, New York. His uncle Collis P. Huntington was the force behind the consolidation of the Southern Pacific Railroad. After the death of his uncle, and determined to make his own mark on the industry, Henry Huntington sold his Southern Pacific stock in 1901 and moved to Los Angeles. He became a major figure in the development of the Los Angeles region through his consolidation of street railroads, public utilities, and large real estate holdings. By acquiring land and then connecting it to the metropolis by electric railroad, Huntington was able to sell suburban parcels at hefty profits.[27]

Huntington's expanding network of street railroads depended on a reliable and inexpensive source of electrical power. In 1902, he joined with Allan C. Balch and William G. Kerckhoff to found Pacific Light and Power Company for this purpose. Kerckhoff was born in 1856 and

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[24] P.M. Downing, O.B. Caldwell, E.R. Davis, W.G.B. Euler, and C.C. MacCalla, "Report of the Sub-committee on Water Development on the Pacific Coast," in National Electric Light Association, *Papers Reports and Discussions, Hydro-Electric and Transmission Sections Technical Sessions, National Electric Light Association Thirty-Eight Convention*, 594-601 (San Francisco: National Electric Light Association, 1915); Federal Power Commission, *Directory of Electric Generating Plants* (Washington, D.C.: Federal Power Commission, 1941), 14-21; U.S. Department of Energy, *Inventory of Power Plants in the United States, 1981 Annual* (Washington, D.C.: U.S. Department of Energy, 1982), 41-54.

[25] Shoup, *Hardest Working Water*, 55-59; Charles A. Whitney, "John Eastwood: Unsung Genius of the Drawing Board," *Montana: The Magazine of Western History*, Summer 1969, 38, 41.

[26] Shoup, *Hardest Working Water*, 60-62; Redinger, *Story of Big Creek*, 6.

[27] Shoup, *Hardest Working Water*, 66.

moved to Los Angeles with his family in 1878. Through his father's lumber company he acquired an interest in the San Gabriel Valley Rapid Transit Railway, which was later absorbed by the Southern Pacific. Balch, born in New York in 1864, was trained as an electrical engineer and managed a steam-electric plant in Portland before moving to Los Angeles in 1896. Together, Balch and Kerckhoff founded the San Gabriel Electric Company, which brought them into contact with Henry Huntington.[28]

Huntington was looking for sources of electrical power, while Balch and Kerckhoff had successfully developed a hydroelectric plant on the San Gabriel River, and were proceeding with plans for another on the Kern River, 100 miles to the north. In 1901 and 1902 the three men founded Pacific Light and Power Company with the short-term aim of supplying cheap power to the street railroads, with the eventual aim of consolidating the electric utilities of the greater Los Angeles area into a monopoly.[29] Initially, 51 percent of the company was owned by the Los Angeles Railroad, in which Henry Huntington held a 55 percent interest, with the remainder owned by the Southern Pacific. Balch and Kerckhoff owned 40 percent of Pacific Light and Power, and appointed three of the seven directors, while Huntington named the rest. In an era where rails dominated transportation, the intimate relationship between power and railroads was evidenced by the fact that the power company was formed as a subsidiary of the railroad, and not the other way around.

Kerckhoff and Balch acquired Fresno's San Joaquin Electric Light and Power in late 1902 as a large source of low cost power that could meet the projected demands of the fast-growing metropolis of Los Angeles.[30] At the time, John Eastwood was Vice President and Chief Engineer of San Joaquin Electric Light and Power. Balch and Kerckhoff were receptive to Eastwood's plans for Big Creek, and hired him in July 1902 to fully plan the system. Eastwood immediately began filing water rights claims and by late 1903 had claimed over 410,000 miner's inches of water in the basin.[31] By 1905, Eastwood had prepared plans for a system of powerhouses and transmission lines that by his estimate would offer considerable savings over similarly sized steam plants.[32] Pacific Light and Power's directors, however, were uncertain whether existing demand could absorb the huge quantities of power that Eastwood's proposed plants would generate, and decided in 1903 to prioritize steam development over hydroelectric. As a result, the period up to 1910 saw little progress on the Big Creek project.

Despite this delay, Eastwood continued to file water claims and began securing permits from the U.S. Department of the Interior to develop the hydroelectric plants, which are located on Federal land on the Sierra National Forest. Road permits were granted in 1903-1904 and comprehensive permits for the initial Big Creek development issued in 1909.[33] In 1906 Pacific Light and Power

[28] Shoup, *Hardest Working Water*, 67-69.
[29] Shoup, *Hardest Working Water*, 74.
[30] Shoup, *Hardest Working Water*, 71.
[31] Shoup, *Hardest Working Water*, 75.
[32] John S. Eastwood, "Comparative Estimate of Cost of Water-Power Transmission Plant vs. Steam Plant, for W.G. Kerckhoff, President, Pacific Light and Power Company," 1905, Document No. 12871, in History and Information File, Northern Hydro Division Headquarters Library, Big Creek, California.
[33] Shoup, *Hardest Working Water*, 82.

reached an agreement with Miller and Lux, a land and livestock company holding much of the downstream water rights on the San Joaquin River, and in late 1905 construction of a road from Shaver (then a timber camp) to the Big Creek basin was begun. Another route, from Auberry to Camp 1 (the site of today's Big Creek town), was begun in 1908.[34]

By 1905, Eastwood had outlined his vision for the initial development of the Big Creek system. He identified the later locations of Powerhouses 1 and 2 as the sites for two powerhouses with 2050' and 1861' of head, respectively. In his proposal, each plant would have six 7,500 horsepower (hp) water wheels generating over 40,000 hp of electricity. His projected power lines were to transmit either at 66kV or 88kV. His design for the powerhouses proposed a separation between the generators, transformers, and transmission equipment:

> The portion to be blasted out will not be great, as the buildings will be narrow, and the outer walls will be carried up, and the floors leveled with broken rock, the buildings rising one above another in steps, the generator house first, the transformer house next, and the line house and tower at the top…
>
> The generator house will be located nearly on a level with the bed rock at the creek, and parallel with the creek channel, the inner edge being blasted out of the bluff, and the outer edge being built up to bring the floor up to a level.
>
> This building will need to be 210 feet long, inside and 40 feet wide, with an alcove to accommodate the exciters and the switching gallery… The transformer house will be separated from the generator room by a fire wall the entire hight *[sic]* of the building, and separate stalls provided for the transformers, and will lighted *[sic]* from a skylight and from windows arranged above the traveling crane, and at the ends of the building, and will be 210 x 30 feet inside.
>
> The line house and tower, will contain the lightning arresters, and the main transmission line terminals, and will be built with a dead wall in front, and lighted from the upper side, and will be 60 feet long and 30 feet wide inside, surmounted by a tower 24 feet square inside, provided with open ports for the exit of the lines.
>
> There is no reason why, with the almost ideal conditions to be met at this site, it should not be a model plant, not only from the point of permanency, economy and certainly of output, but in the way of tasteful and convenient design and architecture as well, in as full a degree as consistant *[sic]* with its location and uses.[35]

Although the eventual design of Powerhouses 1 and 2 departed considerably from Eastwood's original vision, many of the principles laid out in this initial design remained the same: the creekside location, the length of the building, the use of fire walls to separate equipment, and the

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[34] Shoup, *Hardest Working Water*, 83.
[35] John S. Eastwood, "Progress Report for 1903-1904 of Right of Way Surveys and Outline Plan for Power Plant No. 1," 1904, 38-39, in Folder 11, Box 302, Southern California Edison Papers, Huntington Library, San Marino, California.

separation of transformers in stalls. Eastwood was in fact ahead of his time in proposing the physical separation of different functional elements of the plant, an approach to powerhouse construction that become standard after the early 1920s.
He also identified locations for Powerhouse 3 and a larger Shaver Dam (then owned by the Fresno Flume and Lumber Company), and anticipated the use of water from Mono Creek and Mammoth Lakes. As we will see below, all of these facilities were eventually constructed in the locations proposed by Eastwood – although the power eventually supplied by the system was considerably more than even he anticipated.[36]

By 1909-1910, Huntington, Kerckhoff, and Balch began seriously considering the fulfillment of Eastwood's hydroelectric plans. A consultant estimated the cost of the two initial power plants at $12.34 million. To ensure the soundness of the investment, Huntington hired the Chief Engineer of the Southern Pacific Railroad to estimate the potential revenues from the project. The assessment concluded that the Big Creek system would lose money. Rather than canceling the project, however, Balch and Kerckhoff ordered construction of a weir to more precisely calculate water flows on Big Creek.[37]

Meanwhile, Huntington was taking steps to raise capital for the project. Pacific Light and Power Company was recapitalized in late 1909 with the help of eastern bankers and sold new bonds to raise money for the Big Creek project. At the same time, Huntington eliminated the Southern Pacific Company from the project by trading one of his interurban electric lines in Los Angeles for the Southern Pacific's 45 percent stake in the Los Angeles Railroad, Pacific Light and Power's holding company. In 1910, Balch exercised his option to buy the plans, water rights, and permits for Big Creek, all of which were held in Eastwood's name. Eastwood received 10 percent of the stock of the new Pacific Light and Power Corporation.[38] Huntington, however, used special assessments on shareholders to force Eastwood to sell his stock cheaply, depriving him of his hoped-for wealth. Despite his visionary role in designing the Big Creek project, Eastwood was excluded from involvement in its construction and ultimately received no financial reward for his work. Balch and Kerckhoff also sold their interests to Huntington about this time, leaving him with full control of the company. About the same time, in October-November 1911, Huntington secured financial backing from a syndicate of New York bankers that allowed construction to proceed.[39]

Initial Construction, 1910-1913
Once the financial resources to construct the project had been secured, construction was ready to begin. Pacific Light and Power, however, lacked the large workforce or engineering expertise to quickly begin construction. Instead, it hired the Boston-based Stone and Webster Construction Company to design and manage the construction. The contract with Stone and Webster covered the construction of the 56-mile San Joaquin and Eastern Railroad, three dams to create Huntington Lake, Powerhouses 1 and 2, the 240-mile transmission line to Los Angeles, and the

[36] Eastwood, "Comparative Estimate."
[37] Shoup, *Hardest Working Water*, 85-86.
[38] Shoup, *Hardest Working Water*, 85.
[39] Shoup, *Hardest Working Water*, 85, 92.

necessary forebays, tunnels, and penstocks.[40] Authorization to begin construction of the railroad was given on January 26, 1912.

Work on the railroad proceeded in a climate of secrecy, since all of the necessary rights-of-way had not yet been secured. Construction of the railroad raised difficult engineering problems. Most famously, one section of the route passed across a bedrock face on tracks bolted directly to the stone. The railroad was completed on July 12, 1912 – only 165 days after work began.[41]

The development as executed by Stone and Webster followed Eastwood's plans in the main, although Stone and Webster's engineers favored different architectural and engineering solutions: their engineers built Cyclopean masonry dams with gravity sections rather than his proposed earth dams, and combined the generation and transmission facilities in a single structure rather than separating them in detached buildings as Eastwood had proposed.[42]

In March 1912, blasting for the dam sites and tunnels began. Over the summer of 1912, 3,500 men were at work in twelve camps scattered across the construction area. Dam and tunnel construction continued until the end of 1912. Huntington, Balch, and Pacific Light and Power Vice President George C. Ward visited the site of construction in July 1912, in what was to be Huntington's only visit to Big Creek. Preparations for constructing Powerhouses 1 and 2 commenced in late 1912, when Stone and Webster established a sawmill to cut timber logged out of the area. The lumber would be used for construction forms for the powerhouses. At the end of 1912 excavation for the foundations of Powerhouse 1 were well underway.[43] At the same time, the process of securing final permits from the Department of Agriculture (the parent agency of the U.S. Forest Service) continued. Ward filed the application for a final Power Permit on July 16, 1912 with amendments in November. The Department of Agriculture was apparently slow to respond, for Southern California Edison archives contains a letter of March 1913 noting that issuance of the permit was an urgent matter, since construction work was well underway. It was not until July 16, 1913 that the Department of Agriculture finally issued the final power permit for Big Creek Powerhouses 1 and 2.[44]

The pivotal construction year of 1913 opened with bad weather and a general strike. Working conditions were difficult: workers complained of long days and bad food, while typhoid and other diseases struck the camps. Accidents killed or maimed several workers, sparking a visit from the state labor commissioner in late 1912.[45] When several men were fired for trying to attack one of the cooks, over 2,000 men went out on a strike led by members of the Industrial Workers of the World, a radical anarcho-syndicalist union. Demands included time-and-a-half pay for overtime, hot water in the washrooms, better sleeping quarters, access to doctors, and

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[40] Redinger, *Story of Big Creek*, 11; W. Sohier, *The Big Creek Project, A History, December 27, 1917*, typescript, 9-10, in Folder 7, Box 302, Southern California Edison Papers, Huntington Library, San Marino, California.
[41] Shoup, *Hardest Working Water*, 95.
[42] Eastwood, "Progress Report."
[43] Stone and Webster Construction Company, "Progress of the Big Creek Initial Development: Report to Pacific Light and Power Corporation, January 1, 1913," 3, in Water Resources Library, University of California, Berkeley.
[44] Sohier, "The Big Creek Project," 26. More information on Big Creek permits up to 1957 is held in Folder 6, Box 302, Southern California Edison Collection, Huntington Library, San Marino, California.
[45] Shoup, *Hardest Working Water*, 127.

better food. The strike began at Camp No. 3 on January 7 and spread quickly to the others. In response, Stone and Webster closed the mess halls, locked out its employees, and suspended work at Big Creek. Almost 2,000 men were fired outright, and striking workers had no choice but to leave the area.

The record snowfall that fell that week provided a convenient excuse for suspending the project while Stone and Webster hired a new workforce. By January 25, construction on the powerhouses had resumed.[46] Between the strike and the bad weather, however, the Big Creek project had fallen behind schedule. Originally set for completion on July 1 and October 1, 1913, Powerhouses 1 and 2 were not completed until November and December. This delay reduced the projected revenues from the plants, requiring Pacific Light and Power to raise additional funds to complete construction and causing the temporary layoff of some of the construction workforce.[47]

In March, 1913, excavation had been completed and the foundation of Powerhouse 1 was poured.[48] The powerhouse structure was built in just three months, with the roof finished on July 18, 1913. Construction of Powerhouse 2 proceeded simultaneously but was about two months behind Powerhouse 1. The basement of Powerhouse 1 was under construction by May and the roof was in place by October. The generators first went on line on October 14, 1913, though the plant did not begin transmitting power to the Eagle Rock substation in Los Angeles until November 8.

The structure of Powerhouse 2 was almost complete in mid-October of 1913. However, on October 17, 1913, a fire swept through the upper floors of the nearly-complete powerhouse, destroying part of the roof, the internal partitions on the upper floors, and some of the equipment. This fire seems to have been begun accidentally in the small saw mill attached to the construction site, though Southern California Edison's 1922 Valuation of Powerhouse 2 suggests that it was of an 'incendiary nature,' hinting that it may have been a case of arson.[49] Powerhouse 2 Unit 1 did not go online until December 8, 1913, and Unit 2 began transmitting on January 11, 1914.[50]

When the initial phase of Big Creek was complete, the two powerhouses had four generating units producing 80,000 horsepower and using some of the highest heads in the country. At 240 miles long, the power lines connecting Big Creek with Los Angeles were among the world's longest, and set a new record for using 150kV in commercial transmission. The vision of Big Creek as an integrated system of plants which could be added to was also ahead of its time and anticipated the interconnected systems that characterize power production and transmission today.

Other large plants built about this time, such as Keokuk (Illinois) and Conowingo (Maryland), generated more power, but none were built under conditions as difficult as those at Big Creek.

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[46] Shoup, *Hardest Working Water*, 132.
[47] Stone and Webster, "Progress," 3; Kelley, *Valuation*, 8.
[48] Redinger, *Story of Big Creek*, 30.
[49] "Fire at Big Creek Causes Damage of $10,000," *Fresno Morning Republican*, October 20, 1913.
[50] Redinger, *Story of Big Creek*, 31-32.

The difficult mountain terrain, high heads, and huge turbines gave the Big Creek plant an essentially experimental character. *Electrical World* recognized the feats achieved in the initial construction of the system as "one of the most advanced contributions of the engineer to the welfare of civilization."[51]

Intermission, 1914-1919

While Big Creek Powerhouses 1 and 2 were designed for later expansion, the onset of the European war in late 1914 affected both the American credit markets and power consumption. It became difficult for companies such as Pacific Light and Power to raise money for capital projects, while electrical demand in Los Angeles was not growing fast enough to require immediate construction of additional power plants or generating units.[52]

Despite this relative lull, some construction did continue at Big Creek. Crews began work on Tunnel 3, which was to connect Powerhouse 2 to the proposed Big Creek No. 3 development. However, only 2050' of tunnel were bored between July 1914 and February 1920. In summer 1917, the three dams at Huntington Lake were raised to an elevation of 6950', increasing the lake's storage capacity and allowing the later installation of a third generating unit in Powerhouse 2.[53]

More significant for the future development of the Big Creek system was the 1917 merger between Pacific Light and Power (PLP) and Southern California Edison (SCE). Henry Huntington had dreamed since at least 1902 of consolidating southern California utilities under his control. The merger, which was accomplished through a swap of PLP and SCE stock, made sense from a business point of view. PLP had extensive street railroad interests but limited residential service, and the Big Creek plants provided more electricity than it could use. Edison, on the other hand, had a rapidly expanding residential business and was facing a looming shortfall of generation capacity. The two systems complemented each other, as the California Railroad Commission observed when it approved of the merger in 1917. As *Electrical World* noted at the time,

> this merger of what are really vast interests is undoubtedly along the lines of wise business policy. The two electric companies have been operating side by side in a rapidly growing territory, competing keenly for business in a number of centers, and to some extent duplicating investment and wasting energy which could be better utilized in other directions.[54]

The newly merged company had two vice presidents from the Pacific Light and Power side, R.H. Ballard (formerly corporate secretary) and George C. Ward (formerly vice president), while Henry Huntington, his son Howard, and his lawyer W.E. Dunn each took seats on the Board of Directors.

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[51] "The 150,000-Volt Big Creek Development—I," *Electrical World*, January 3, 1914, 33.
[52] Shoup, *Hardest Working Water*, 153.
[53] David H. Redinger, "Progress on the Big Creek Hydro-Electric Project, Part I," *Compressed Air Magazine*, December 1923, 722.
[54] "Merger of California Hydroelectric Systems," *Electrical World*, December 9, 1916, 1134.

After the end of the First World War in late 1918, an economic boom began. Capital was again available, and rapid urban and industrial growth in Los Angeles had radically increased demand for electricity. A new source of energy was needed quickly. As a result, the previously modest expansion plans for Big Creek were accelerated.[55] In October 1920 Southern California Edison applied to the California Railroad Commission for approval of their proposal to expand Powerhouse 1 and construct two new powerhouses, to be called Powerhouse 3 and Powerhouse 8. Permission was granted in Railroad Commission decision 8569 on January 20, 1921.[56]

The original plans for Powerhouse 3 had called for it to utilize a head similar to Powerhouses 1 and 2 (1500'). The development of more efficient vertical turbines in the intervening years, however, made it possible to extract more power from a lower head. As a result Edison decided to divide the head originally intended for Powerhouse 3 into two power plants. Powerhouse 8 (so numbered because numbers up to 7 had already been used in Federal permit applications) was to be built first at the junction of Big Creek and the San Joaquin River. The construction of Powerhouse 8 in early 1921 set off a period of continuous expansion of the Big Creek system that lasted, almost without interruption, until 1929.

The Big Creek Community on the Eve of the Great Expansion

The 1920 United States Census was conducted just as the great expansion of the Big Creek system was getting underway. While the population of the region would eventually swell to over 5,000 at the height of construction work, only 535 people lived in the "Cascada Precinct" of Fresno County when the census was conducted in 1920. The precinct included the town of Cascada (renamed Big Creek in 1926) and the nearby construction camps. The census data provides us a snapshot of the community and its demographics that provides some insight into the social world of Big Creek in the early period of its operation.[57]

The Big Creek community in 1920 was overwhelmingly male, with 426 adult men but only fifty-eight women and fifty children. There were only fifty-two married couples in the community, although ninety-four men were listed as married. While some of the married couples took on individual boarders, most of the men lived in boarding houses or bunkhouses with from ten to fifty-six occupants. This dense occupancy is reflected in the fact that the area contained only seventy-nine dwellings for 535 people.

Twenty-three of the married couples had children. Of the fifty-eight women residing in the Cascada precinct, fifty-two were married, three widowed, and three single. Two of the single women, aged 19 and 21, were the eldest daughters of a foreman. The other, aged 21, was the grammar school teacher. Two of the widowed women, aged 61 and 60, lived in Big Creek with their working sons. A 35 year-old widow, living with her 7-year-old son, was the proprietor of one of the boarding houses.

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[55] Shoup, *Hardest Working Water*, 162.

[56] Noted in an untitled memorandum in Folder 6, Box 302, Southern California Edison Collection, Huntington Library, San Marino, CA.

[57] Fourteenth Census of the United States, Cascada Precinct, Fresno County, California, 1920, on file at University of California, Berkeley.

The vast majority of employment in the Cascada Precinct was through Southern California Edison: of the 432 adults with jobs, 365 worked for the "power company" or within a "power company camp." Another thirty-five men worked for the San Joaquin and Eastern Railroad, also owned by Southern California Edison. Twenty men worked in construction, at a warehouse, or in a sawmill – possibly the employees of the Fresno Lumber and Irrigation Company in the town of Shaver, now Shaver Lake. The remaining residents, twelve in number, were shopkeepers, hotel operators, or providers of other basic services. Cascada, in other words, was a company town fully dependent on the Big Creek powerhouses.

Over half (189) of the Edison employees were recorded in the 1920 census as "laborers." Others had more skilled employment as carpenters (35), mechanics or machinists (18), engineers (18), electricians (10), teamsters (13), and clerks. Other jobs included blacksmiths, timekeepers, painters, miners, riggers, pipefitters, and cement workers. Supporting the community were fourteen cooks, twelve waiters, five storekeepers, four boarding house workers, two nurses, a doctor, and a grammar school teacher. The average age of Edison employees at the time of the census was thirty-seven.

Most residents of the Big Creek area in 1920 were native-born Americans, and all listed their race as "white." Only around one third were foreign born, and most of these had come from northwest Europe. More than twenty nations of origin were represented in the community. The largest group was Irish (21), followed by English (16), Swedish (14), Canadian (13), German (12), Scottish (8), Italian (8), and Russian (7). All of the foreign-born came from either Europe or Canada, except one from Siberia, one from Chile, and one from South Africa. Over two-thirds of the foreign-born workers, however, had been in the U.S. more than ten years.

Powerhouse 8: The "Ninety Day Wonder"

This community would soon be swelled by the addition of thousands of new construction workers. The great expansion of the Big Creek system began in early 1921, when the construction of Powerhouse 8 began. Excavation for the foundation of Powerhouse 8 took place between January and early May, with the first concrete was poured for its foundation on May 12. The turbine parts were assembled as concrete was being poured for the powerhouse structure, and installation of Unit 1 commenced in June. On August 11, Powerhouse 8 began generating power, and was connected to the system on August 16.[58]

Powerhouse 3: "The Electrical Giant of the West"

In September 1921, soon after the completion of Powerhouse 8, construction began on the tunnels, forebays, and penstocks for Powerhouse 3.[59] The revised plan for this station was similar to that of Powerhouse 8: it would also use Francis-type vertical reaction turbines operating under a relatively low head (827'). The engineering challenges of Powerhouse 3 were considerable, requiring 30,000' of tunnel work, the blasting of a six-mile road into a sheer granite face, and extensive foundation excavation. This work continued throughout 1922.

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[58] "Big Creek No. 8 Hydro-Electric Unit Completed," 160.

[59] "Southern California Edison to Start 150,000-Kw. Station," *Electrical World*, September 24, 1921, 636.

On November 15, 1922 the excavation for the Powerhouse 3 forebay was complete and the erection of concrete forms was begun.[60] The dam was completed in February 1923. Excavation for the foundation of the powerhouse started June 5, 1922 and was completed January 10, 1923. The three initial units of Powerhouse 3, "the electrical giant of the West," were placed online on September 30, October 2, and October 5, 1923.[61] Though Big Creek 3 was planned for eventual expansion to six units, the structure as built in 1923 had room for only four, while only three were installed at first. Even with only three units, however, Big Creek Number 3 was the largest hydroelectric plant in the west, with an aggregate capacity of 75,000kW. The powerhouse also incorporated several innovations in design, such as an outside switchyard and a two-level generating floor that eliminated the need for a basement.[62]

Additional Units and 220kV Transmission

Each of the Big Creek powerhouses was designed for later expansion. Work on a third generating unit at Big Creek No. 2 was authorized in late 1918 and began in summer 1920. Structural work was completed that November, and the new unit was paralleled to the system on February 1, 1921. The Shaver Tunnel was also begun in February 1920 and completed in May 1921. This tunnel diverted water from Shaver Lake into the Big Creek drainage, allowing its use in Powerhouse 2 and the plants below. Initially this water was simply diverted into the Powerhouse 2 forebay, though it was later used in Powerhouses 2A, 3, and 8 upon their completion.

Work to convert Big Creek's 150kV transmission system to 220kV was completed on May 6, 1923, when the Big Creek system began transmitting at the highest voltage used commercially anywhere in the world.[63] In July 1923 Powerhouse 1 was expanded to add a third unit, which was brought on line on July 12. In late 1924 and 1925 Powerhouses 1 and 2 were expanded to their full planned capacity by the addition of a fourth unit to each. This addition required extension of the powerhouse structures by 56' each.[64]

Florence Lake, the Mono-Bear Conduit and Shaver Dam

The later 1920s saw efforts to increase the available water in the Big Creek system by increasing storage capacity and drawing from adjacent watersheds. Between 1925 and 1928, tunnels and dams were built from Mono Creek, Bear Creek, and the south fork of the San Joaquin, while the dam at Shaver Lake was raised to increase its storage capacity.

The years 1925 and 1926 saw the construction of the dams that created Florence Lake on the south fork of the San Joaquin River. Work on the Florence Lake Tunnel (later named the Ward Tunnel for Edison President George C. Ward), which connected the south fork watershed to the

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60 Redinger, "Progress I," 838.

61 David H. Redinger, "Progress on the Big Creek Hydro-Electric Project, Part V," *Compressed Air Magazine*, September 1924, 991.

62 "Work Progressing Rapidly on Big Creek No. Three," *Journal of Electricity and Western Industry*, May 1, 1923, 341.

63 "Transmission at 220,000 Volts a Fact," *Electrical World*, May 12, 1923, 1107.

64 "Big Creek No. 2 Power House Being Extended 56 ft.," *Journal of Electricity* 54 (6): 297; Southern California Edison, "Memorandum, Hydro Generation, Northern Division, Generator Winding Data Revised to May 13, 1985," 1-2, on file at Southern California Edison Northern Hydro Division headquarters, Big Creek, CA.

Big Creek system, had begun in 1920 and was finished in April 1925. For the dam, a multiple-arch design was chosen, a type pioneered by John S. Eastwood. Construction began in March and was completed in November 1925, although the dam was raised again in 1926.[65] The Mono-Bear diversion drew water from Bear and Mono Creeks, located downstream from Florence Lake, into the Ward Tunnel and thence into Huntington Lake. Constructed between 1925 and 1927, these tunnels required excavation through solid granite.[66]

Shaver Lake, originally built by the Fresno Flume and Lumber Company as part of their logging and sawmill operation, was raised between 1925 and 1927, expanding the lake to 2,200 acres in surface area. The new Shaver Lake was designed to store excess water from Florence and Huntington Lakes and also to make possible new high-head generating units that would be known as Powerhouse 2A.[67]

Powerhouse 2A and the End of the Great Expansion

The availability of water from Florence Lake and Shaver Lake led to the ambitious expansion of Powerhouse 2. Two additional units were constructed in a new building adjacent and connected to the older building. Powerhouse 2A would harness a 2,418' head, the highest in the Big Creek system and one of the highest in the United States. Construction of Powerhouse 2A began in June 1926 and cost $23 million.[68] Units 1 and 2 went online on August 21 and December 21, 1928, respectively.[69] The 56,000 hp turbines and 46,500kW generators were among the largest in the world at the time of their installation. Although Powerhouse 2A drew water from Shaver Lake and had its own transmission line, the new building was operated from the Powerhouse 2 control room.[70]

When the second unit of Powerhouse 8 went on line in June 1929, the great expansion of the Big Creek system was concluded.[71] Fifteen generating units were in service, with a aggregate capacity of 344,800kW. The system went from generating 213 million kilowatt-hours in 1914 (its first full year of service) to 1.6 billion kilowatts in 1928.[72] From the opening of Powerhouse 1 in 1913 to the end of 1929, the Big Creek system had set a series of records for generation and transmission that earned it a preeminent place among the electrical generating systems of the west and of North America.

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[65] Redinger, *Story of Big Creek*, 136, 150.
[66] Redinger, *Story of Big Creek*, 149.
[67] Redinger, *Story of Big Creek*, 153.
[68] "Southern California Edison's Advance," *Electrical West*, April 21, 1928, 829.
[69] Southern California Edison, "Memorandum," 3.
[70] Redinger, *Story of Big Creek*, 157; "Southern California Edison's Advance," 829.
[71] "Second Unit Installed at Big Creek Plant No. 8," *Electrical West*, July 1, 1929, 38.
[72] Southern California Edison, *1928 Annual Report, Big Creek Division*, 21, in History and Information File, Northern Hydro Division Headquarters, Big Creek, California.

Powerhouse	Unit	Capacity (kW)	Installation date
1	1	14,000	1913
	2	14,000	1913
	3	14,000	1923
	4	22,400	1925
2	3	14,000	1913
	4	14,000	1913
	5	14,000	1921
	6	14,000	1924
8	1	22,400	1921
	2	34,000	1929
3	1	25,000	1923
	2	25,000	1923
	3	25,000	1923
2A	1	46,500	1928
	2	46,500	1928
Total	**15**	**344,800**	

Table 1. Big Creek Generating Capacity at the end of the Great Expansion.

Operating the Powerhouses

The degree to which the Big Creek powerhouses, especially Powerhouses 1 and 2, were experimental technologies can be seen in the daily operators' logs, which remain on file at the plants. The logs reveal how operators dealt with frequent minor mechanical problems, and a few major ones such as penstock breaks. The experience led to innovations in safety procedures, and a focus on accident avoidance that remains a characteristic of Southern California Edison corporate practice today.

JOB CLASSIFICATIONS

Big Creek Nos. 1 and 2 began operation in late 1913 with three to five men on duty. Shifts were initially ten hours, but were reduced to 8 hours by 1920. The plants maintained a three-shift schedule: 8am-4pm, 4pm-midnight, and midnight-8am. These rotations were also observed in Big Creek Nos. 3 and 8 when they came on line in 1921 and 1923 respectively. In 1929 the Big Creek division employed forty-nine powerhouse operators in the four plants, at the grades of "shift operator," "operator," "assistant operator," and "probationer." Besides the operators, each powerhouse had a station chief, assistant chief, electrician, machinist, two utility men, and a cook for the boarding houses.[73]

A shift schedule prepared by Big Creek 8 station chief P.H. Hilbert in early 1926 provides an example of how these classifications were divided into shifts:

	{Shift Operator
A.M Shift	{Switchboard Operator
	{Relief Asst. Operator
	{Asst. Station Chief
Day Shift	{Switchboard Operator
	{Machinist or Electrician
	{Shift Operator
P.M. Shift	{Switchboard Operator
	{Relief Operator or Electrician

Hilbert notes that in this arrangement, the station machinist and station electrician would be each available for maintenance work for twelve days each month.[74] Plant daily logs show that other plants also maintained a workforce of three or four men per shift during the 1920s.

OPERATOR TASKS

The main task of the powerhouse operators was to adjust power production to fluctuations in load on the overall Edison system, which were dependent on demand in the greater Los Angeles area. Most of the operators' daily tasks, however, were more mundane. They included testing equipment, performing routine maintenance, and cleaning the station. The daily log for December 18, 1926 from Big Creek 3 gives the flavor of the work:

> 12 midnight. Hess, Batzer, Morgan – on. Thompson – off.
>
> Station normal. Greased #3 Turbine and swept kitchenette, washroom, and office. Cleaned door, sinks, urinals, bowls, and tubs in main washroom. Emptied trash barrel from machine shop. Burnt all garbage and swept hallway. Cleaned up a few grease stains on gen. floor.
>
> 8am. Lockyer, Leahy, Horr – on. Morgan – off.
>
> Station normal. Repaired opening bolt #15 unit #3 turbine. Took voltage of batt. Swept part of gen. floor. Ran purifier #1 turbine, about 20 gal's water. Wiped #2 turbine.
>
> Station duties – Horr.

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[73] See Southern California Edison, *1927 Annual Report, Big Creek Division*, 29 for operator grades, and *1929 Annual Report, Big Creek Division*, 4, both in History and Information File, Northern Hydro Division Headquarters, Big Creek, California.

[74] P.H. Hilbert to R.B. Lawton, "Big Creek No. 8 Operating Shift Schedule," memorandum dated February 19, 1926, in File 29-940.1, Archive Room, Big Creek Powerhouse 8.

4pm. Lee, Strain, Thompson – on. Horr – off.

Station O.K. Wound Venturi Meters. Wiped #1 Turbine and room. Took specific gravity of station batteries and of three cells of A and B Carrier Current Telephone Batteries. Cleaned windows along North wall on generator floor. Cleaned and mopped Kitchenette. Greased #1 H. [house] Set, and water pumps. Changed pumps and compressors.

Station duties – Thompson.[75]

The handwritten logs, which are extant for all four powerhouses, offer meticulous detail about the working lives of their operators during the period of significance.

THE EVOLUTION OF SAFETY PRACTICE

The Big Creek plants deployed cutting-edge technology for their day. Innovation, however, brought with it both hazards and significant technical challenges. In the early period of operation it was the penstocks in particular which provided many of the mechanical failures in the plant. The first such incident occurred at Powerhouse 1 just after 1 am on December 1, 1913, only a few months after the plant was placed in service. A broken penstock joint sent water and debris cascading down the hill and against the back wall of the plant. A.C. Prigmore, the station chief, reported:

> Tried to notify Mr. Lawton by phone but found telephone line shorted and sent up messenger, by this time water had raised up back of building to the window sills and rear door gave way letting flood in between agitators thru be plates of exciters and down into basement. Notified Eagle Rock we would have to shut down at once… Water level in generator pits [was] about a foot and a half above bottom each. Entire length of basement passage filled with sand and rubbish to within a foot of the ceiling, most of it comming *[sic]* in from opening at the West end of building. Sand and rocks covered the floor around the agitators to the top of the foundations.[76]

It took two weeks to return the plant to operative condition.

A worse accident occurred on March 14, 1924, at Big Creek No. 3. A machinist named Johnson and his helper Childs were working on a stuck plunger valve inside Penstock Number 3 when water rushed into the pipe. As the investigative committee reported:

> The helper was close to the manhole and succeeded in getting out. Johnson was caught and killed, his body being torn to pieces and forced out through the turbine relief valve. Water was discharged through the manhole and tore a large hole in the roof, spouting a hundred feet or more above the powerhouse. Part of the air duct for #3 generator was torn away and several windows between the generator room and gallery were broken. The power house was flooded, several inches above the main floor.[77]

[75] Big Creek No. 3, *Floor Log Volume 11 (1926-1927)*, 97, in Archive Room, Big Creek Powerhouse 3.
[76] Big Creek No. 1, *Daily Log*, December 1, 1913, in Archive Room, Big Creek Powerhouse 1.
[77] Battey, et al., letter to Mr. B.F. Pearson.

Johnson's death led to serious introspection in the Big Creek Division. The investigative committee determined that the accident occurred because "responsibility [was] divided between operating and construction organizations and the lack of definite rules as to obtaining clearances to do construction and repair work."[78]

In response, the committee recommended improvements to mechanical safety, including mechanical locks on valves and disconnection of electricity to forebay gates during penstock maintenance. They also recommended that definite rules be established for obtaining maintenance clearances. The procedures suggested by the committee were implemented quickly. Powerhouse daily logs and floor logs from the mid-1920s show that new clearance forms were used when maintenance was required on potentially dangerous machinery such as valve pits and governors. The forms named the employee cleared to do the work, and were countersigned by the station chief and dispatcher. The apparatus itself was checked by two further employees, and the final clearance to begin the work was then signed by the foreman on duty.[79] By ensuring that everyone on duty knew that the work was being performed, the new procedure responded to the failures in communication that were evident in the 1924 tragedy.

Beyond these specific procedures, an increasing emphasis on safe working conditions evolved in the Edison organization during the 1920s. Weekly letter reports and annual reports prepared by Station Chiefs track the number of injuries and days lost to illness, with evident pride when the numbers remained low. The Big Creek Division Report for 1927, for instance, notes only 296 hours off for sickness and 164 off for injury out of 244,078 payroll hours – barely one-fifth of 1 percent:

> A mistake in switching at Big Creek #3 on June 12, 1927, is the only mistake we have to report for the entire Big Creek Division.
>
> Big Creek Plants numbers 1 – 2 and 8 have a clear record for two years. No avoidable accidents to employee in any plant.
>
> A great deal of credit is due to Careful Clubs, Station Chiefs and Employees for the interest they are taking in this branch of the work.
>
> The Big Creek Division Maintenance Crew has a clear record for the last two years. No accidents or mistakes resulting in damage to property or injury to person.[80]

The company established Careful Clubs to provide safety training at each powerhouse, with rewards for stations and individuals for maintaining a clean safety record for periods of six months, one year, and two years. This emphasis on safety practice represents the early phase of the 'safety first' culture that remains a hallmark of Big Creek operations today.

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[78] Battey, et al., letter to Mr. B.F. Pearson.
[79] An example of this form can be seen in Big Creek No. 3, *Floor Log Volume 12 (1927)*, 193, in Archive Room, Big Creek Powerhouse 3.
[80] Southern California Edison, *1927 Annual Report*, 28.

RETENTION AND TRAINING
Given the isolation and harsh winter climate of the Big Creek area, recruiting and retention of skilled employees was an ongoing problem. In an early 1922 letter to Southern California Edison's Superintendant of Generation, the Big Creek superintendant wrote of the difficulties he faced:

> As the annual vacation period is near at hand, and it will be necessary at that time to secure relief for the three Big Creek plants, writer would suggest that an effort be made to secure a better class of men than we have been getting in the past. By a better class of men I mean men that have received at least a high school education, and some technical as well if possible, and who have had some mechanical and electrical experience…We have filled our plants with men who in the majority of cases were simply looking for a job. The result is that out of the entire Big Creek operating organization, only a very small percentage have the inclination or ability to fit themselves for responsible positions. The operation of the plants and system is going to become increasingly difficult and complicated by the addition of more and larger plants and units, automatic and semi-automatic protective equipment and increased transmission voltage and in the writer's opinion is going to require a much higher grade of men to successfully and properly handle this equipment than we have been getting the last few years.[81]

Another dimension of the problem was the very high employee turnover experienced at Big Creek, especially in the construction workforce. As the shareholder magazine *Edison Partners* magazine reported in 1923:

> Under the plan of permanent organization of the construction forces the labor turnover on the Big Creek-San Joaquin project has been constantly decreasing, until the average for the past year was forty per cent, and the lowest average for any month twenty-six percent. Good living conditions, excellent food, commissary stores which sell everything from clothing to cigarettes at the same prices that obtain in the large cities, amusements, recreation halls, and greatest of all, that intangible thing which can perhaps be termed "camaraderie" and co-operation tend to contentment among the men, and a desire to consider the project in the nature of a life work.[82]

Despite the rosy prose, the writer concedes an average of forty percent turnover *per month* in the construction workforce, suggesting that many of the workers on the construction jobs at Big Creek during this time found the work too hard, the conditions too isolated, or the pay too low to remain on the job for more than a short time.

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[81] R.B. Lawton to D.D. Morgan, "Operating Force—Big Creek," undated memorandum, probably 1922, in File 29-929, Archive Room, Big Creek Powerhouse 8, Big Creek, CA.
[82] "Contented Labor," *Edison Partners*, 6.

This level of turnover may have been specific to the Construction Department.[83] The 1927 Annual Report for the Big Creek Division shows that only thirty-seven of 139 employees left during the year, an annual turnover rate of 26.6 percent (or 2.2 percent per month). Of these, fourteen received transfers within the Edison organization, "in most cases at the request of the company."[84] While this remains a high rate, it suggests that the permanent operating employees at Big Creek had more satisfaction with their work.

To address these problems, Edison implemented programs in the mid-1920s to improve employee education and retention. These often began with basic mathematics. As Big Creek 3 Station Chief O.C. Bangsbury reported in 1927:

> As has been requested, regular classes will be held once a week, starting with Shop Arithmetic. The class has been organized and the first meeting is scheduled to be held Wednesday evening, April 27th. A record is to be kept of each member's work and the progress of the class will be kept in step with that of the classes at the other plants so that men transferring from one plant to another will have no difficulty in continuing with the work.[85]

This policy was implemented throughout the Big Creek system. The 1927 *Annual Report* notes that the number of employees enrolled in study programs increased from 52 percent in 1926 to 68 percent in 1927.[86] At the same time, recruitment of new employees seems to have improved: the 1928 Divisional Report noted that "a number of high grade men have been sent in" but also that "the labor turnover, with this class of men, will be somewhat greater… especially college men, are not satisfied to remain as plant operators."[87] The Big Creek management faced a dilemma: intelligent and educated employees were needed to staff the complex powerhouses, but these same people could also find jobs elsewhere in less isolated places than the mountains around Big Creek.

Edison did make efforts to provide amenities and community-building measures to encourage employees to stay. For instance, losses were anticipated in the commissaries and cookhouses provided for the construction workforce, and the total losses averaged into the cost of construction of the powerhouses.[88]

Though many single men remained in bunkhouses, married men and supervisors often became eligible to live in one of the cottages constructed in Big Creek and at the camps close to the lower powerhouses.

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[83] Employees on the construction jobs were hired through the Southern California Edison Construction Department, while operating employees were employed by the Big Creek Division (later the Northern Hydro Division) of the Power Generation Department.
[84] Southern California Edison, *1927 Annual Report*, 27. Similar figures are reported in the 1928 and 1929 annual reports.
[85] O.C. Bangsbury, "Weekly Letter Report, B.C. 3, April 16, 1927," 2, in Archive Room, Big Creek Powerhouse 3.
[86] Southern California Edison, *1927 Annual Report*, 29.
[87] Southern California Edison, *1928 Annual Report*, 13.
[88] In Arthur Kelley's unit cost developments and price books for the Big Creek plants, these losses are included in the cost of materials and labor, suggesting that the company saw these subsidies as a routine construction expense.

> Their pretty cottage homes, which surround the powerhouses, are equipped with everything that is newest and best in sanitation and electrics. Some of the powerhouse colonies have lawn tennis courts and swimming pools; new books are carried to the powerhouse people from nearby public libraries at frequent intervals, and every now and then a welfare agent comes along with a portable motion picture machine, and shows them the latest "movies."
>
> To "The People Who Live in the Powerhouses" the radio has been a great blessing. They get the news of the day and night as it is read by the broadcasters in the big newspaper offices, and the listen to the entertaining lectures and beautiful concerts which the radio service of the city newspapers is now providing.[89]

The company also sponsored a social institution, the Edison Clubs, which were located at each powerhouse and in Big Creek.[90] The Edison Clubs sponsored dances, kept a library and newspaper subscriptions, and organized other events such as card parties, picnics, film screenings, and miniature golf outings. Outside of Big Creek town, the powerhouses also maintained small commissaries. The clubs were maintained by a combination of employee dues (.50 per month in 1931) and company subsidies.[91]

Big Creek in Context

Between late 1911, when construction began on Big Creek Powerhouse 1, and 1929, when Powerhouse 2A was completed, the Big Creek region was transformed from inaccessible wilderness to an industrial landscape and company town intimately connected to the economy of greater Los Angeles. Each phase of the great expansion was marked by pioneering technical achievements in transportation, dam building, tunnel driving, powerhouse design, and transmission line construction. In the process, a community developed that was marked by a combination of pioneer spirit and corporate paternalism. For many who worked in Big Creek, such as David Redinger, the experience was one that defined their lives.

TECHNOLOGY AND STRUCTURAL DESIGN

Structural Design and Plant Layout

Powerhouse 8 is comprised of two engaged buildings that form a rough 'T'. The bar of the 'T' is the generator building, while the leg of the 'T' holds the transformer, switches, switching equipment, control room, and offices.[92] The narrative that follows refers to these two structures as the "generation building" and the "switching building." The foundation of the generation building is composed of reinforced concrete and reaches to bedrock in the forebay of the powerhouse. The main generator floor is located at 2250' elevation, and above this level both the generation building and the switching building are constructed of reinforced concrete around a

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[89] "People Who Live in the Powerhouses," *Edison Partners*, 11.

[90] For more discussion of the Edison Clubs and their social role, see Shoup, *Life at Big Creek*, 6-8.

[91] Edison Club #28, "Minutes of regular monthly meeting, held Thursday, October 5th, 1933," in Archive Room, Big Creek Powerhouse 2/2A; Edison Club #21, "Minutes, Regular Meeting, December 3, 1931," in Archive Room, Big Creek Powerhouse 1.

[92] "First 220,000-Volt Station Completed," *Electrical World*, December 3, 1921, 1115-1119.

structural steel frame. On initial construction the east side of the generation building was composed of a temporary corrugated iron wall.[93]

As originally constructed the generation building measured 90' by 56'-8". The main generation space is framed along the north and south elevations by five structural columns spaced 16' apart. The last structural column and the northwest corner of the building are 22'-11¾" apart. Two structural columns support the walls on the east and west ends of the building, spaced 16' from each other and 18'-10" from the corners of the generation building (CA-167-G-49).

The internal space consists mostly of a single large room holding the two turbines, their governors and exciters, the oil pump, and the traveling crane, with additional equipment in the basement:

> The basement of the generator portion of the power house building contains the water turbine, Johnson valve, oil filter, humidifier, emergency camp water supply pumps and storage tanks for transformer and switch oil. The main floor of the generator section contains the main generator, house generator, governor and governor oil pumps, water circulating pumps and machine shop.[94]

Inside this space, the Unit 1 turbine and generator was placed on the central axis of the building in the middle of the generating room. Views CA-167-G-12 through CA-167-G-14 show the interior of the main generating floor.

The western end of the generation building had four floors of office and utility rooms. The first floor of this section held a toilet, service room, shop and pump room, and storeroom. The second floor held the main control room, shown in Views CA-167-G-26 through CA-167-G-28. Another toilet and a 220V switch room for station service power were also located on the second floor. The third floor held the station chief's office and the storage battery room (View CA-167-G-55), but the fourth floor is shown as empty in the original 1921 plans (CA-167-G-49, CA-167-G-51).

On the addition of Unit 2 in 1929, the building was extended 38 feet eastward. The new east façade was identical to the west façade, making the building symmetrical. The second unit was also laid out along the central axis of the generation building and mirrored the position of the first unit (CA-167-G-58, CA-167-G-59).

The three-story transmission building held the four transformers, low-tension and high-tension buses, switchboard, and offices. As Kelley notes,

> The four 20,000 kVA transformers are on the main floor of the transformer building which has the same elevation as the main floor of the generator section… Successive floors in the transformer portion of the building contain the 220,000 volt oil switches and

[93] Kelley, *Valuation*, 65; Kelley, *Unit Cost Development and Price Book*, 44.
[94] Kelley, *Unit Cost Development and Price Book*, 44.

disconnecting switches, the 11,000 volt main generator switch, main generator field switch and rheostat, and a storeroom.[95]

The second and third floors each contained one 220kV oil switches; the transmission lines connected to the 220kV bus in the rear portion of the third floor. See CA-167-G-52, CA-167-G-54, and CA-167-G-56 for details of the transmission building.

Mechanicals and Operation

General

Hydroelectric plants such as Big Creek Number 8 convert the mechanical force of falling water into electrical energy through electromagnetic induction. Water flows through long tubes known as penstocks and is then directed through a nozzle onto the buckets of the turbines, causing them to rotate. The turbines are directly connected to the generator shaft, causing it to turn. A governor is attached to each wheel, allowing the operator to control the speed of the wheel by reducing or increasing water flow against the buckets.

The generator consists of two magnetized copper coils, one rotating (rotor) and the other stationary (stator). To generate power, the rotor coils must be energized by the input of direct current (DC) from an exciter (a separate motor or generator), which produces a magnetic field. The rotation of the magnetized rotor field against the stator windings produces electromagnetic flux and induces alternating current (AC) in the stator's output terminals.

Current from the generators is sent through step-up transformers, which increase the voltage to a level desirable for transmission, and then into transmission lines leaving the plant. Between the generator and transformer, low-tension bus rooms allow electric current from the generators to be sent to different banks of transformers. Between transformers and transmission lines high-tension bus rooms allow current to be switched between different transformer banks and transmission lines. Having parallel sets of generating, bussing, transforming, and transmission equipment allows generation to continue even when individual elements of the system must be taken offline for maintenance or due to mechanical problems.

Hydraulic equipment in the plant was supplied by Allis-Chalmers (Unit 1) and Pelton Water Wheel (Unit 2). Electrical equipment was from General Electric, with the exception of some minor equipment manufactured by Westinghouse. Although it began transmitting at 150kV, the powerhouse was designed to produce power at 220kV. When the conversion of the Big Creek power lines for 220kV transmission was completed in May 1923, Big Creek 8 was the first plant in the world to transmit power commercially at such a high voltage.

Hydraulic

Penstocks

Powerhouse 8 drew its water via tunnels from Power House 2/2A. The Unit 1 penstock was 2700' long and manufactured in part by the Lacy Manufacturing Co., with the rest from the M.W. Kellogg Co.[96]

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[95] Kelley, *Valuation*, 44-45.

The Unit 2 penstock was approximately 2,700' long and narrowed from 120" to 87" in diameter.[97]

Turbines
The two turbines in Powerhouse 8 are vertical-shaft, single runner Francis-type reaction turbines, a different design than those in neighboring Powerhouses 1, 2, and 2A but similar to those in Powerhouse 3. A reaction turbine is one in which the water changes pressure inside the turbine: the inner vanes of the turbine are spirally curved and diminish in diameter. Following the law of conservation of angular momentum, the water pressure increases as the diameter of spin diminishes. This makes the transfer of energy from the water to the vanes of the turbine more efficient. Due to their suitability for use with low heads, reaction turbines are today the most common type of turbine for hydroelectric power production.

Francis turbines are reaction turbines that combine radial and axial flow. In other words, water spirals not only toward the center of the turbine (radially) but also downward (axially). "Vertical shaft" refers to the fact that the central bearing shaft of the unit is set vertically, so that the turbine and generator rotate in the horizontal plane. A "single runner" unit is one that uses a single water wheel to turn the generator (many horizontal units use two wheels, one on each side of the generator). In Powerhouse 8, the main generators are in effect stacked on top of their turbines.

Unit 1 is powered by an I.P. Morris vertical Francis-type reaction turbine, installed in 1921. The turbine produces 30,000hp under a 680' head at a speed of 428 rpm.[98] The Unit 2 turbine, installed 1929, is also a vertical Francis-type reaction turbine, but was purchased from the Pelton Water Wheel Company. It produces 44,000hp under 715' head at a speed of 375 rpm.[99] Plans of the Unit 2 turbine foundations can be seen in View CA-167-G-59.

Governors
Turbine governors control the speed of the turbines by regulating water flow. They control the needle valves at the end of the intake nozzles, allowing variation of the flow of water against the turbine buckets.

Unit 1 was installed with an I.P. Morris double floating-lever governor with a Taylor control system. Governor control systems allowed powerhouse operators to set speed parameters for the generator, so that it could rapidly change speed in response to fluctuations in load and not supply more than a predetermined amount of power. The Taylor system also permitted the governor to be set for hand control.[100] Unit 2 used a Pelton enclosed oil pressure type governor for the main turbine.[101]

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[96] Kelley, *Valuation*, 102.
[97] Kelley, *Valuation and Unit Cost Development*, 4.
[98] Kelley, *Valuation*, 116.
[99] Kelley, *Valuation and Unit Cost Development*, 38.
[100] Smith, "Big Creek Plant," 188.
[101] Kelley, *Valuation and Unit Cost Development*, 40.

House Turbines and Governors
Units 1 and 2 were each provided with a house turbine and governor, which provided energy for both the exciters and station light and power. The Unit 1 house turbine was a 205hp Allis-Chalmers type B-1 horizontal impulse wheel operating at 750 rpm under 700' of head. It was purchased on Allis-Chalmers contract No. 17998 and bore serial number 699.[102] The governor for this turbine was a Woodward type LR hydraulic governor.[103] The Unit 2 house water wheel was a 300hp Allis-Chalmers single jet impulse wheel operating at 750 rpm under 670' net effective head, and supplied with a Woodward governor.[104]

Electric
Generators
The Unit 1 generator was manufactured by General Electric and was rated for 28,000kVA (24,000kW) at 11kV and 428rpm. It was purchased on General Electric Contract No. 16899 and bears serial number 3096295. The generator was direct-connected to its exciter and had a motor-operated braking mechanism.[105]

Unit 2 was installed in 1929 and was also manufactured by General Electric. The 35,000kVA generator was designed to generate 50-cycle power at 11kV and 375rpm or 60-cycle power at 13.2kV and 450 rpm. It bears General Electric serial number 4099417.[106] Views CA-167-G-58 and CA-167-G-60 show plan views of the generator. The current appearance of the generators can be seen in Views CA-167-G-15 through CA-167-G-17.

House (Station Service) Generators
The Unit 1 house generator, also from General Electric, generated 150kw at 240 volts and was mounted on the same shaft as the Unit 1 exciter.[107] The Unit 2 house generator was an Allis-Chalmers Co. 250 kVA model, generating at 240V and 750 rpm.[108] View CA-167-G-19 shows one of the house generators.

Exciters and Subexciters
The Unit 1 exciter was supplied by General Electric direct connected to the generator, meaning that it was mounted on the same shaft, above the generator and turbine.[109] The Unit 2 exciter installed in 1929 was a General Electric direct connected main field exciter, 330kw, 375/450rpm, 1320A, 250V, bearing serial number 1449554.[110]

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[102] Kelley, *Valuation*, 117.
[103] Kelley, *Valuation*, 119.
[104] Kelley, *Valuation and Unit Cost Development*, 40.
[105] Kelley, *Valuation*, 124.
[106] Kelley, *Valuation and Unit Cost Development*, 46.
[107] Kelley, *Valuation*, 124; Kelley, *Unit Cost Development and Price Book*, 239.
[108] Kelley, *Valuation and Unit Cost Development*, 46.
[109] Kelley, *Unit Cost Development and Price Book*, 239.
[110] Kelley, *Valuation and Unit Cost Development*, 46.

With the installation of Unit 2 in 1929 it was decided to add subexciters to the plant – in other words, smaller exciters which provided excitation for the main exciters. The subexciters were provided by General Electric and provided 15kW at 350V.[111]

Low-tension Bus

The low-tension bus consisted of General Electric Type H6, triple pole, single throw, 15kV oil switches.[112]

Transformers

On initial construction in 1921, Powerhouse 8 was supplied with four General Electric 8333kVA, 220kV transformers 10 feet in diameter and 13 feet high.[113] Three of these were active and one supplied as a spare. These were the first 220kV transformers installed for commercial use anywhere in the world, and when Big Creek system was converted to 220kV in May 1923, they were the first to use such a high voltage in commercial transmission.

As *Electrical World* reported in 1921, the transformers

> involve some new features of construction. The fact that they are to be connected without resistance to a permanently grounded system made possible the attachment of the line terminal to the middle of the coil stack and the attachment of the neutral to the top and bottom of the coil stack. With this arrangement ample creepage distance to ground is obtained along the supporting and insulating cylinders within the dimensions of the coil stack.[114]

In late 1926, the 8233kVA models were replaced with an equal number of General Electric indoor type WC, 20000 kVA transformers under GE Contract No. 35719.[115]

Views 37-V050, 38-V051, and 39-V052 show an antique transformer on the third floor of the switching building, possibly one of the 20000 kVA units installed in 1926.

High-Tension Bus

The high-tension switches were oil circuit breakers of General Electric Type K-039-71BF-7. *Electrical World* magazine noted that these units set records for size when installed in 1921. The 220kV oil circuit breakers, which were also furnished by the General Electric Company, were set in large cylindrical oil tanks and had the largest bushings ever supplied for commercial switches. The main oil switches were connected directly to the transmission lines with no intervening switches, a simplification from previous designs.[116]

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111 Kelley, *Valuation and Unit Cost Development*, 46.
112 Kelley, *Unit Cost Development and Price Book*, 239.
113 "First 220,000-Volt Station Completed," 1117.
114 "First 220,000-Volt Station Completed," 1117.
115 Kelley, *Unit Cost Development and Price Book*, 297.
116 "First 220,000-Volt Station," 1118.

Lightning Arrester
The lightning arrester used for the 6.6kV station power line from Powerhouse 2 was a General Electric Type I, 4-tank aluminum cell electrolytic lightning arrester, rated for 4680-7250 volts.[117]

Control and Maintenance
Control Room
The control room was located in the eastern end of the generation building. According to Kelley, the switchboard was

> of the General Electric Company continuous closed type, 90" high, with dull black grill at end and grill doors. The switchboard consists of two auxiliary swinging panels, two front border panels, right and left ends, one main bench section and auxiliary sections mounted in rear of the bench system.[118]

The contemporary configuration of the control room is visible in Views CA-167-G-26 through CA-167-G-28.

Crane
The powerhouse was served by a Shaw 150 ton crane, supplied by Western Manning, Maxwell, and Moore under Contract 17362.[119] The run of the crane was extended in 1929 to match the new building length. This crane is visible in views CA-167-G-12 and CA-167-G-13.

Alterations and Additions
Powerhouse 8 suffered a penstock break soon after it went into operation, on August 20, 1921. The surge of water and debris into the powerhouse damaged the temporary end wall and some of the equipment and wiring; however, repairs proceeded quickly and the plant was operational again within a few days. Another penstock break, on New Year's Day 1924, did not damage the powerhouse.[120]

Other changes to the plant in the mid-1920s were minor. In 1925, barrier walls were constructed between equipment in the 220kV switch room on the second floor of the switching building. The work was undertaken under General Work Order 029010.[121] The transformers were also replaced in 1926 in anticipation of plant expansion. As Kelley notes:

> Following the decision to start work on the installation of the second unit at Power House No. 8, the original bank of 8233 kVA transformers at Power House 8 was removed and a bank of 20000 kVA transformers installed in its place. This work was complete in 1926 and was the last work of importance done at Power House 8 prior to the actual installation of the second unit.[122]

[117] Kelley, *Unit Cost Development and Price Book*, 239.
[118] Kelley, *Unit Cost Development and Price Book*, 240.
[119] Kelley, *Valuation*, 67.
[120] Kelley, *Valuation*, 9.
[121] Kelley, *Unit Cost Development and Price Book*, 63.
[122] Kelley, *Valuation*, 10.

The generation building of the powerhouse was extended approximately 38 feet in 1929 to accommodate the addition of the second generating unit (see construction narrative for details).

Besides routine maintenance, the only major change in the plant for the next decade came in 1934, when the Unit 1 turbine was reconstructed and upgraded. In 1946 parts were purchased to convert the plant to 60-cycle power, which was completed in 1947. New governors were placed on Unit 1 and Unit 2 in 1947 and 1952, respectively. In 1960, the 220kV transformers and oil circuit breakers were replaced after over thirty years of service.[123]

CONTEXT AND SIGNIFICANCE

Preservation

Environmental Setting

The landscape around Powerhouse 8 remains mostly undeveloped and has changed little since its construction in 1921. The area around the plant has seen minor changes due to the installation of new equipment and an additional penstock for Unit 2.

Structural/Façade/Exterior

The façade of Powerhouse 8 was expanded 38 feet in 1928 to accommodate Unit 2. This expansion, however, was part of the original plans for the plant and is aesthetically consistent with the original design. Otherwise, the exterior of the plant appears much as it did on initial construction. Window sash is original, and the façade detail has not been altered.

Interior

The interior of the generation building, including the turbines and generators, appears very similar to its appearance in 1929 after the installation of Unit 2. Routine maintenance has been performed on the equipment, including replacement of turbine buckets and rewinding of generators. However, the turbines, generators, and many gauges remain in their original casings.

The excellent state of preservation, continuity of use, and integrity of setting appear to present sufficient integrity to convey the significance of the structure.

Significance

Big Creek Powerhouse 8 is a NRHP-eligible structure of statewide significance, part of a district of national significance. As the discussion above suggests, the powerhouse retains substantial structural and functional integrity.

Constructed in 1921, Big Creek Powerhouse 8 was part of the great expansion of the Big Creek system by Southern California Edison between 1920 and 1929. Planned and constructed quickly to help ease a power crisis in Southern California Edison's Los Angeles-area service territory, Big Creek 8 marked a number of firsts. It was among the first plants to use the improved Francis-type vertical turbine, which allowed high efficiencies at relatively low heads. It set records for

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[123] Don Dukleth, "Changes to Powerhouse 8 after 1929," memorandum supplied to consultants, based on Southern California Edison Northern Hydro Division Annual Reports, 2009.

the speed of its construction, just 100 days from groundbreaking to operation. Powerhouse 8 was the first plant in the world designed for transmission at 220kV, and in 1923 was the first in the world to transmit commercial power at that voltage. It also reflects the architectural trend toward separating generation and transmission equipment at power plants: these functions are segregated in separate buildings.

The Big Creek system is also significant in the history of the Los Angeles region. Conceived as a means of powering both residential development and electric railways, power from Southern California Edison's Big Creek plants was instrumental in the rise of suburban development in the region. The system is closely associated with railroad, energy, and development magnate Henry Huntington; with Edison executives and power pioneers A.C. Balch, William Kerckhoff, and George C. Ward; visionary California hydroelectric engineer John Eastwood; and longtime Big Creek manager David Redinger.

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- Plant Accounting Department, Southern California Edison Company, Rosemead, California
- Northern Hydro Division Headquarters, Southern California Edison Company, Big Creek, California
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- Big Creek Powerhouse 2/2A, Big Creek, California
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Likely Sources Not Yet Investigated

The consultants are not aware of likely sources that have not yet been investigated.

Appendix A
Historical photographs of Big Creek Powerhouse 8 are held in the Southern California Edison collection at the Huntington Library, San Marino, California. The following photographs in the collection illustrate the plant from the mid-1920s to the 1950s.

- 15666
- 15667
- 15948
- 15495
- 15943
- 15942